



Energy Maintenance Technologies Ltd

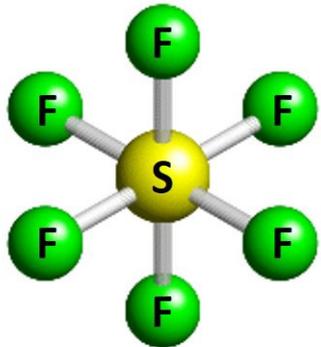
## Insulating gas analysis considerations for transitioning from SF<sub>6</sub> to alternatives

**Neil Gwinnutt**

VP Global Sales & Technical Services

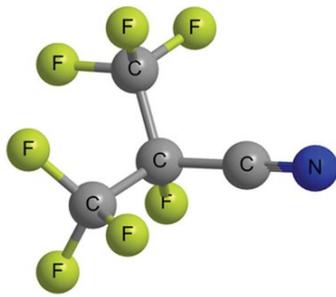
## Available Insulating Gases\*

**SF<sub>6</sub>**



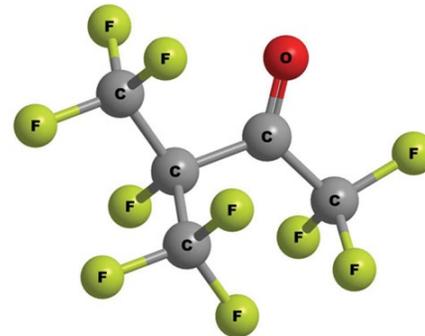
**C4-FN**

(Novec 4710™, G<sup>3</sup>™, EconiQ™)



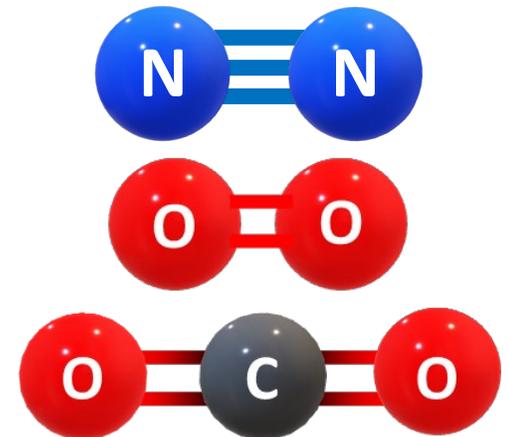
**C5-FK**

(Novec 5110™, AirPlus™)



**Air**

(Dry, Clean, Pure, Gases of Natural Origin)



\* Additional Hydrofluoro-Olefins (HFO) based insulating gases in development by OEMs

# When Analysis & Maintenance Was Easy...

**SF6**

Gases	IEC 60376:2018	IEC 60480:2019
SF <sub>6</sub>	✓ >98.5% Vol	✓ >97% Vol
H <sub>2</sub> O	✓ <200ppm	✓ <200ppm
SO <sub>2</sub>	✓ <7ppm	✓ <25ppm
Air	✓ <1% Vol (10,000ppm)	✓ <1% Vol (10,000ppm)
HF	✓ <7ppm	✓ <25ppm
CF <sub>4</sub>	✓ <0.4% Vol (4,000ppm)	✓ <3% Vol (30,000ppm)
CO*	✗	✗
H <sub>2</sub> S*	✗	✗

\* CO & H<sub>2</sub>S analysis required in other territories such as China for more detailed fault finding and asset health

- Easy to detect and differentiate breakdown products and their source
- Fittings: Relatively easy, typically DN8/DN20, Malmquist etc
- Pressures: <140psi
- Measurements: In ppm or %Vol
- Low cost, easy to manage, still popular in emerging economies



IEC Standards for Alternative Gases still in development:

- **IEC 63359 Specifications for the re-use of mixtures of gases alternative to SF6**
  - Working Group formed, 1<sup>st</sup> meeting held,
  - 2<sup>nd</sup> meeting planned for August
- **IEC 63360: Mixtures of gases alternative to SF6**
  - CDV out for final review; estimated publish in 2023

**C4-FN**

(Novec 4710, G3, EconiQ)

**C5-FK**

(Novec 5110, AirPlus)

**Air**

(Dry, Clean, pure, Gases of  
Natural Origin)

# IEC Alternative Gas Standards: IEC63360

Gases	IEC 63360 contaminants
C4-FN	>99.7% Vol C4-FN, <270ppm H2O, <0.3% Vol "Other"
C5-FK	>99.5% Vol C5-FK, <270ppm H2O, <0.5% Vol "Other"
O2	>99.5% Vol O2, <200ppm H2O, <0.5% Vol "Other"
CO2	>99.5% Vol CO2, <200ppm H2O, <0.5% Vol "Other"
Compressed Air	77-80.5%Vol N2, 19.5-22%Vol O2, <5000ppm CO2, <200ppm H2O
Synthetic Air	80%Vol N2 ( $\pm 2\%$ ), 20% Vol O2 ( $\pm 2\%$ ), <200ppm H2O, <0.4% Vol "Other"
N2	>99.7% Vol N2, <200ppm H2O, <0.3% Vol "Other"
HFO1336mzzE	>99.3% Vol N2, <200ppm H2O, <0.7% Vol "Other"

**C4-FN**

(Novec 4710, G3, EconiQ)

**C5-FK**

(Novec 5110, AirPlus)

**Air**

(Dry, Clean, pure, Gases of Natural Origin)

# Alternative Gas Analysis Standards

- No standardization on fittings connections for differing insulating gas types, nor differing blends...

Gas / Gas Mixture	Colour	RAL	Connection
SF6	Pure Orange	2004	DILO DN8 with M26 thread or DILO DN20 with M45 thread
N <sub>2</sub> / O <sub>2</sub> mixtures	Light Blue	5012	DILO DN12 with M30 thread or DILO DN20 with M50 thread
Mixtures containing C4-FN (C <sub>4</sub> F <sub>7</sub> N)	Yellow Green	6018	DILO DN8 with M28 thread or DILO DN20 with M48 thread
Mixtures containing C5-FK (C <sub>4</sub> F <sub>10</sub> N)	Telemagenta	4010	DILO DN8 with M24 thread or DILO DN20 with M43 thread
CO <sub>2</sub> / O <sub>2</sub> mixtures	Dusty Grey	7037	Malmquist valve with M32 thread

CO<sub>2</sub> 100%

N<sub>2</sub> 80%, O<sub>2</sub> 20%



SF6 100%

C4-FN 2%, CO<sub>2</sub> 95%, O<sub>2</sub> 3%

C4-FN 5%, CO<sub>2</sub> 95%

C4-FN 5%, CO<sub>2</sub> 92%, O<sub>2</sub> 3%

C5-FK 5%, CO<sub>2</sub> 95%

## C4-FN

(Novac 4710, G3, EconiQ)

## C5-FK

(Novac 5110, AirPlus)

## Air

(Dry, Clean, pure, Gases of Natural Origin)

# Alternatives “In Use” Gas Analysis

Gases	Newly Mixed	Faulted Gas	Approved Detection Techniques
C4-FN	3% to 30% Mol	Reduced Concentration	Infrared, Speed of Sound
C5-FK	3% to 30% Mol	Reduced Concentration	Infrared, Speed of Sound
CO2	70% to 95% Mol	Increased Concentration	Infrared
O2	1% to 10% Mol	Reduced Concentration	Echem, Paramagnetic
H2O	<200ppm	Increased Concentration	Infrared, capacitive
CO	0ppm	>2000ppm (60,000ppm seen)	Echem
HF	0ppm	>500ppm (>1000ppm seen)	Infrared, Echem
CF4	0ppm	>2000ppm (>5000ppm seen)	Infrared

**C4-FN**  
(Novec 4710, G3, EconiQ)

**C5-FK**  
(Novec 5110, AirPlus)

- With so many C4/C5 “recipes” it is likely there will be no limits imposed on the Primary Gas concentrations for IEC 63359, end users will be referred to the manufacturer for guidance
- Chilled mirror technology cannot be used for H2O measurements in C4/C5 mixtures
- “Bad” gas determined by presence of key breakdown gases

# Alternatives “In Use” Gas Analysis

Gases	Newly Mixed	Faulted Gas	Detection Techniques
N2	70-95% Vol	Reduced Concentration	Calculation
O2	1% to 30% Vol	Reduced Concentration	Echem, Paramagnetic
H2O	<200ppm	Increased Concentration	Infrared, Capacitive, Chilled Mirror, QCM
CO2	70% to 100% Vol	Reduced Concentration	Infrared
CO	0ppm	>500ppm	Echem, Infrared
NO	0ppm	Approx 10 to 60ppm <sup>1</sup>	Echem, Infrared, UV
NO2	0ppm	Approx 50 to 300ppm <sup>1</sup>	Echem, Infrared, UV

- With so many N2/O2 & CO2 “recipes” it is likely there will be no limits impose on the Primary Gas concentrations for IEC 63359, end users will be referred to the manufacturer for guidance
- “Bad” gas determined by presence of key breakdown gases

<sup>1</sup> Makoto Miyashita, Koma Sato et al, Mitsubishi Electric Corp to be published in ISH2023

**Air**  
(Dry, Clean, pure, Gases of Natural Origin)

- **Analysis & maintenance of SF<sub>6</sub> alternative insulating gases is now more of a challenge – Cocktail Mixing**
  - New detection techniques being used, some SF<sub>6</sub> techniques now not suitable
  - Potentially multiple analysers required just for one substation
  - Homogenization of the gases – when to test?
  - % Mol or % Vol results?
  - What fittings are required.



**SF<sub>6</sub>**

**C4-FN**

(Novec 4710, G3, EconiQ)

**C5-FK**

(Novec 5110, AirPlus)

**Air**

(Dry, Clean, pure, Gases of Natural Origin)

- Result Interpretation**

- Understanding what gases you have and what constitutes a “bad gas, this will be vital as poor results and understanding can lead to much higher levels of post analysis works compared with SF6

SF6 Insulating Gas	C4/C5 Insulating Gas	Air Insulating Gas
H <sub>2</sub> O	H2O	H2O
SO <sub>2</sub>	CO2	CO2
CO	CO	CO
HF	HF	HF
CF <sub>4</sub>	CF4	NO2
SOF <sub>4</sub>	COF2	NO
SF <sub>4</sub>	C2F6	O3
S2F10	CF3-CN	
H2S	CF3-CF2-CN	

**SF6**

**C4-FN**

(Novec 4710, G3, EconiQ)

**C5-FK**

(Novec 5110, AirPlus)

**Air**

(Dry, Clean, pure, Gases of Natural Origin)

- **Planning & Logistics**

- Making sure you have an all-in-one analyzer or multiple analyzers (and fittings/hoses) that are right for the job
- Calibration and servicing requirements for multiple instruments – making sure each analyzer is within certification
- Ensuring analyzer maintenance is upheld, not just swapping sensors; servicing of components such as O-rings, seals, compressors vital with new gases

- **Training**

- Training on potentially multiple instruments
- Gas blend identification and competency to ensure results are fully understood
- Understanding where ppm, %Mol and % Vol are used and how blends change

**SF6**

**C4-FN**

(Novac 4710, G3, EconiQ)

**C5-FK**

(Novac 5110, AirPlus)

**Air**

(Dry, Clean, pure, Gases of Natural Origin)

- Market moving quickly
  - Supply chain issues regarding alternatives.
  - IEC still working with C4
  - OEMs still committed to C4, investing further in solutions,
- New technologies emerging – analysis, blending, mixing, leak detection
- Huge investments being made by analyser and technology companies to address these challenges

**SF6 will still be around in the short to medium future, but the reduction challenge is being tackled and the end is in sight...**

**SF6**

**C4-FN**

(Novac 4710, G3, EconiQ)

**C5-FK**

(Novac 5110, AirPlus)

**Air**

(Dry, Clean, pure, Gases of Natural Origin)



**Thank you**

**Any questions?**